DEVELOPMENT AND EXPERIMENTATION USING A LOW COST ROAD ROUGHNESS DEVICE

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A Thesis submitted in partial fulfillment of the requirements for the award of the Degree of

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by

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Under the guidance of
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CERTIFICATE

This is to certify that the thesis entitled "**DEVELOPMENT AND EXPERIMENTATION USING A LOW COST ROAD ROUGHNESS DEVICE**" submitted by **Mr. SHANTI SWAROOP** in partial fulfillment of the requirements for the award of Master of Technology Degree in Civil Engineering with specialization in Transportation Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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ABSTRACT

Road surface roughness is an important measure of road condition for maintenance of the existing road condition, as it is an important factor for ride quality, vehicle operation cost, travel speed and comfort. Roughness level of road pavement surface is generally represented by IRI obtained by field measurement using BI, MERLIN, NAASRA, ROMDAS etc.

In this paper use of three different type of instrument named MERLIN, Auto Level, and new device is described and their results are analyzed to validate the measuring capabilities of the newly fabricated device. As there are a lot of roughness measuring devices are present in the market but they are either costly, difficult in handling or regular calibration is required to operate them. So an attempt has been made to design an economic and easy handling device to measure the roughness of the road.

Key words: Roughness, IRI, BI, MERLIN, NAASRA, ROMDAS, Auto level,

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List of Abbreviations

IRI	International Roughness Index
RTRRMS	Response Type Road Roughness Meters
ROMDAS	Road Measurement Data Acquisition System
UI	Unevenness Index
BI	Bump Integrator
NAASRA	National Association of Australia State Road Authorities
CRRI	Central Road Research Institute
TRL	Transport Research Laboratory

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Road roughness is the deviation of a road surface from an imaginary true planar surface with characteristic dimensions that influence vehicle dynamics, ride quality and pavement drainage as defined by the American Society for Testing and Materials (ASTM). It is otherwise defined as the longitudinal unevenness of road surface (Cundill, 1991). It is one of the key indicators to evaluate road performance and condition. Roughness affects safety, comfort, travel speed and vehicle operating costs. Therefore, roughness has been considered as one of the key factors to make a decision for further road works. Road roughness, or smoothness, reviews are performed to monitor the pavement conditions in order to evaluate the ride quality of new and restored or rehabilitated pavements. Roughness is primarily related to serviceability, structural deficiencies and road deterioration (Chang et al 2009).

Roughness can be determined in different ways by considering the amount of vertical displacement that is felt by the passenger while moving over a section of road. The units in which roughness is measured are IRI, NAASRA, ride number etc. Generally roughness is inversely proportional to the factors like comfort, safety, travel speed and vehicle operation cost, i.e. the higher the roughness of the road the lesser the above factors.

1.2 OBJECTIVE OF THE RESEARCH

- Study available literature on roughness measurements.
- Use a new concept to design and develop a low-cost road roughness measuring instrument.
- To measure the road roughness in certain specific road stretches using the developed equipment and other available methods in order to draw a comparison and finally decide the viability of the developed set-up with respect to its measuring capabilities.

1.3 ORGANISATION OF THESIS

The thesis consists of five chapters as described below:

- Chapter 1 describes the general idea about the road roughness, objective of the research and methodology.
- Chapter 2 deals with the review of literature and study of previously done works.
- Chapter 3 describes the development and design of new roughness measuring device.
- Chapter 4 explains the analysis of results.
- Chapter 5 discusses the conclusion and future scope of study on this area of research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter focuses on the review of literature covering roughness on pavements. This includes the mechanism and working principle of conventional instruments to calculate the road roughness along with their merits and demerits.

2.2 ROUGHNESS MEASURING INSTRUMENTS

Pavement profile measuring systems started with straightedge devices in the early 1900s. Other simple profiling devices, such as profilographs and response type road roughness measuring systems (RTRRMS) were developed in the late 1950s and 1960s. Highway agencies mainly adopted the profilographs for measuring initial road roughness of newly constructed pavement between the late 1960s and 1980s. In the 1980s and early 1990s, use of inertial profilometers in observing the pavement condition increased (Wang, 2006).

There are basically three groups of roughness measuring instruments are available.

- The class I instruments are the static road profile measuring devices e.g. auto level and rod, which are simplest in concept. Here surface undulations are measured by level difference of the surface by taking a reference point of known elevation at starting of the survey. But these devices are very slow in use and considerable amounts of calculation are involved in deriving roughness index from the measurement data taken.

Two recent devices which are also static road profile measuring devices which work on the same principle as the earlier one but are semi-automated are the TRRL Abay beam (Abaynay - aka 1984) and the modified ‘Dipstick profiler’ (Face Company). With both of these instruments, the surface undulations are measured from a static reference point and data is fed directly into a microprocessor to give the result. This gives high quality results, but they are also slow in operation and costly.

- The second class of instrument is the dynamic profile measuring device, such as the TRRL high-speed profilometer (Still and Jordan 1980). In these instruments, road roughness is measured with respect to a moving platform equipped with some means of compensating for platform movement, so that the true road profile can be derived. These device gives good quality results, but also expensive. Here roughness survey can be done at a greater speed as compare to class I instruments but they are not suitable for very rough roads.

- Finally, the class III instruments are the response type road roughness measuring systems (RTRRMS). These measure the cumulative vertical movements of a wheel or axle with respect to the chassis of a vehicle while moving over a road section as per the deviation of the profile. In the case of a standard device such as the towed fifth wheel bump integrator (Bl) (Jordan and Young 1980), the response is directly used as a roughness index. But in other devices such as the vehicle-mounted Bl, the response is converted to a standard roughness by some means of calibration equations. However towed fifth wheel BI is expensive and requires careful operation but the vehicle-mounted Bl is cheaper than the former one and performs well as long as it is calibrated regularly.

There are basically four types of BI, firstly half car BI where single BI used in solid rear axle. Secondly the quarter car BI where dual BI used with independent rear suspension two at each rear wheel and single BI used at one of the rear wheel. The last one is the towed fifth wheel BI.

Indian Practice

Towed fifth wheel bump integrator is generally used in India and the roughness value (Unevenness Index (UI)) is reported in mm/km. To derive IRI value from UI values the bump integrator needs to be calibrated for specific set of parameters using dipstick profiler. CRRI has developed a relationship between IRI and UI. The following equation shows the typical relationship.

$$IRI = UI / 720$$

2.3 INTERNATIONAL ROUGHNESS INDEX (IRI)

The International Roughness Index (IRI) is the standard roughness index used for the correlation among the instruments and to facilitate the exchange of roughness-related information. It is calculated using a quarter-car vehicle model, whose response is collected to give a roughness index having units in/mi, m/km etc. The IRI was defined as a mathematical property of a two-dimensional road profile showing elevation as it varies with longitudinal distance along a travelled track on the road which can be calculated from slopes of the profiles obtained with any valid measurement method, starting from static rod and level surveying equipment to high-speed inertial profiling systems (The World Bank, 1982).

Sayers et al. (1982) conducted an experiment named "The international road roughness experiment (IRRE)" in Brazil as road roughness is gaining increasing importance as it is an important factor for the evaluation of road condition, both in terms of road pavement performance, and as a major determinant of road user costs. The experiment was to determine the correlation among the roughness, calculated using different types of instruments and to encourage the adaptation of an International Roughness Index (IRI) to provide the exchange of roughness-related information. The "roughness" of a road defined in this report as "The variation in surface elevation that induces variation in traversing vehicles ".

IRI VALUE RANGE

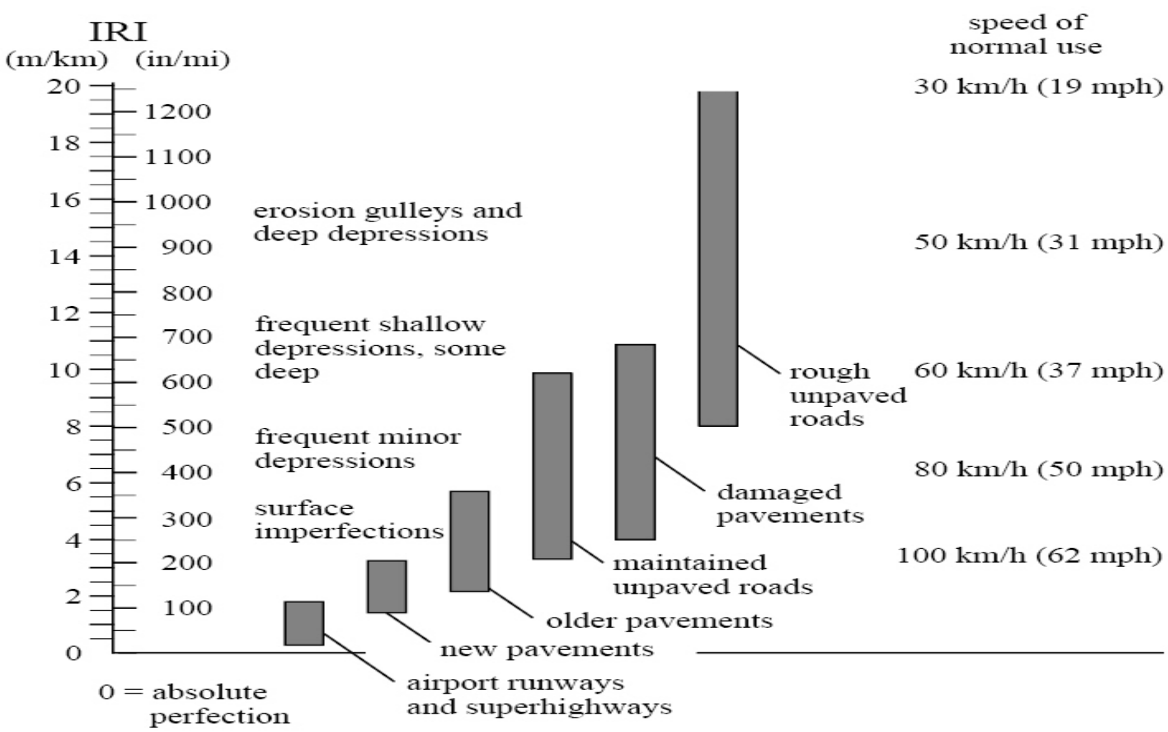


Fig 2.1 IRI Value Range

(www.pavementinteractive.org/wp-content/uploads/2007/08/Iri1.jpg)

The fig. 2.1 shows the different IRI ranges for various types of road conditions. The IRI value range shown here are represented in the unit m/km and in/mi. Speed of normal use of vehicles on different roads having different IRI values are also shown on the right side of the figure.

Rashid and Tsunokawa (2008) researched on the Causes and developed Remedial Measures for Potential Bias of Response Type Road Roughness Measuring Systems. As commonly used response type road roughness measuring systems are not free from speed constraint and are not suitable for any survey speed or speed fluctuations. As the instructed speed can't always be maintained to do the survey they developed an alternative calibration equation that eliminates speed constraint.

Barsi et al. (2004) presented a low-cost photogrammetric based road surface measurement system, which was designed and developed by the Department of Photogrammetric and Geoinformatics. The initial concept of the system was to create measurement instrumentation, which have laser module to mark independent points that can be identified by image processing algorithms and therefore can be used for photogrammetric spatial intersection computations.

Chang et al. (2009) used an Autonomous Robot with vertical displacement sensors and laser to measure International Roughness Index (IRI) to replace manually driven equipments. The equipment moves along the test path at a speed of up to 3 km/h, automatically stops at each 15 cm sampling interval to measure the vertical displacement. He anticipated that in near future this automated robot can be replacing the manually driven equipment.

Johannesson et al.(2014) observed considering just a single wheel path along the road is over simplification as any four wheel may subjected to excitation due to road roughness in the left as well as right wheel path. So he gave a model for roughness of road profiles on parallel tracks using roughness Indicators. A statistical model for road profiles along parallel tracks has been proposed and validated. Here the data are measurements of surface irregularity along two parallel tracks.

Susilo et al. (2001) compared the roughness measurement values of different roughness measuring devices. They gave a relationship between IRI value and output variables from MERLIN, NAASRA, ROMDAS, and dipstick and gave a conclusion on their research work that to measure a roughness level for road with IRI value less than 2.13, it is better to use a NAASRA device and for road with IRI value in the range of 2.13 and 8.90, it would be better to use a ROMDAS device. To measure road roughness with IRI value higher than 8.90, it would be better to use a NAASRA measure device. For road with IRI value less than 9.00, ROMDAS give IRI value smaller that of NAASRA. In the contrary, for road with IRI value higher than 9.00, ROMDAS give IRI value greater that NAASRA. But finally they concluded that NAASRA and ROMDAS IRI values don’t have significant difference with respect to standard device.

Das, J. B. (2014) developed a new low cost roughness measuring instrument with water level concept where roughness can be measured at certain interval (manual input given) and analyzed using software up to a great extent of accuracy as compare to MERLIN and Auto Level.

Cundill, M A (1991) used MERLIN to get roughness (D) and developed relationship between IRI and D by MERLIN for all type road users. $IRI = 0.593 + 0.0471D, 42 > D > 312 (2.4 > IRI > 15.9)$ Also described relationship between BI and MERLIN. He also derived equation for relation between BI and D for asphaltic concrete, gravel and surface treated road at 32km/h speed of BI.

2.4 MERLIN

2.4.1 INTRODUCTION

MERLIN is a Machine for Evaluating Roughness using Low-cost Instrumentation. Modified roughness measuring machine is a simple machine to measure roughness, which determines the surface deviation from an imaginary planar surface. The details of MERLIN as described by Cundill (1991) are mentioned in the following paragraphs. It is a manually operated instrument and it’s particular attractions are that it is cheap, simple to operate and self calibrating. Also it measures displacement to less than a millimeter.

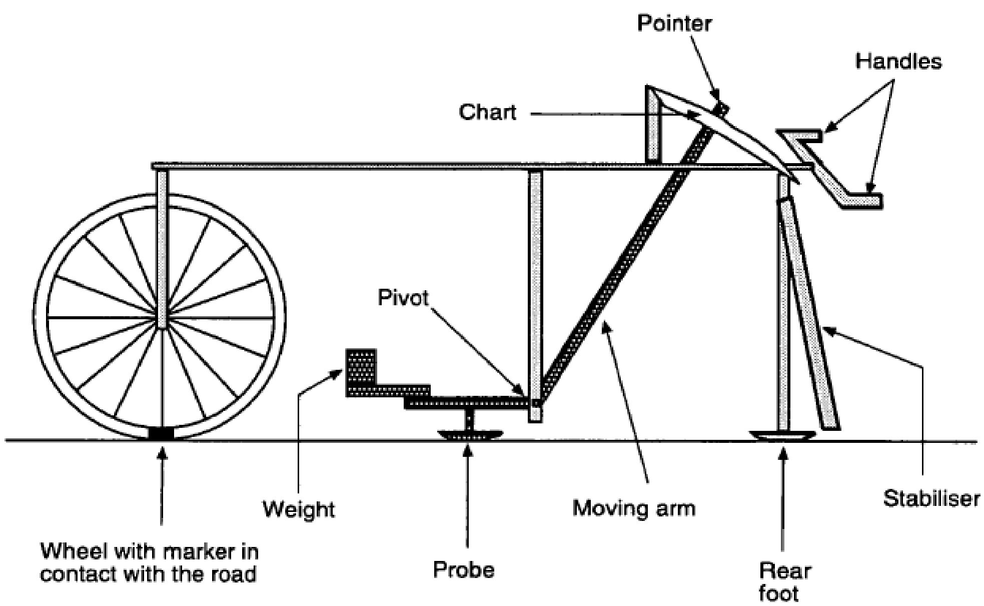


Fig 2.2 MERLIN showing different parts

(Cundill, 1991)

2.4.2 GENERAL DESCRIPTION AND PRINCIPLE OF OPERATION

The figure 2.2 demonstrates the MERLIN. Working principle of MERLIN is based on 'mid chord deviation' of the probe with respect to the two feet attached on both end of the device. The probe lies exactly mid way between the two feet at 0.9 m distance from each. The device measures the vertical displacement between the road surface beneath the probe and the imaginary line joining the two feet on the road surface. So the deviation is known as 'mid chord deviation' (Cundill 1991).

Here the measurements are at each one completion of rotation of the wheel. The greater the roughness of the road the greater will be the variability of the displacement. These displacements are recorded by means of a histogram on a chart mounted on the instrument by putting cross marks in the box of the histogram where the pointer is placed as per the movement of the probe.

Fig 2.3 Road roughness measurement using MERLIN in progress

2.4.3 ROUGHNESS EQUATIONS

The IRI can be measured from D as follows.

For all road users

$IRI=0.593+0.0471D$ ($42>D>312$ and $2.4 > IRI > 15.9$)

Where IRI is measured in terms of m/km and D is measured in terms of mm (which is 90^{th}percentile spread of readings from the graph) (Cundill, 1991)

2.5 AUTO LEVEL

2.5.1 INTRODUCTION

Auto level or automatic level is an automatically operated optical instrument that aides in checking points on the horizontal planes. This device helps in estimating the horizontal surface in other words to find the level of a horizontal plane, which might be in a small or larger scale for surveying. There various types of these are available with different specification for various jobs. (Das, 2014)

(a) **(b)**

Fig 2.4 Auto Level used for roughness measurement

2.5.2 GENERAL DESCRIPTION AND PRINCIPLE OF OPERATION

The fundamental principle of leveling lies in finding out the separation of level lines passing through a point of known elevation (B.M.) and that through an unknown point (whose elevation is required to be determined). The details of Auto Level as described by Das (2014) are mentioned in the below paragraph.

Auto level is an optical device which provides height reference with respect to a reference point of known elevation called datum. This reference is a horizontal plane through the axis of the telescope, known as the "Height of Collimation" or instrument height. Once the instrument height is measured the height of other stations can be found by measuring from this plane with a staff. The height of collimation is found by taking a back sight to a staff placed on a bench mark. The staff reading is added to the bench mark value to obtain the height of collimation. The level of different points can be found out and then these values are subtracted from the previous one to get level difference.

(a) (b)

Fig. 2.5 Roughness survey using Auto Level in progress

2.5.3 CALCULATION OF IRI

Here IRI can be obtained from average slope as follows for 220 m interval and 200 readings

Slope = Difference in readings at each interval / 220

Average slope = sum of total slope / 200

IRI = average slope * 1000 (in m/km) (Das, 2014)

CHAPTER 3

DEVELOPMENT AND EXPERIMENTATION OF NEW DEVICE

3.1 INTRODUCTION

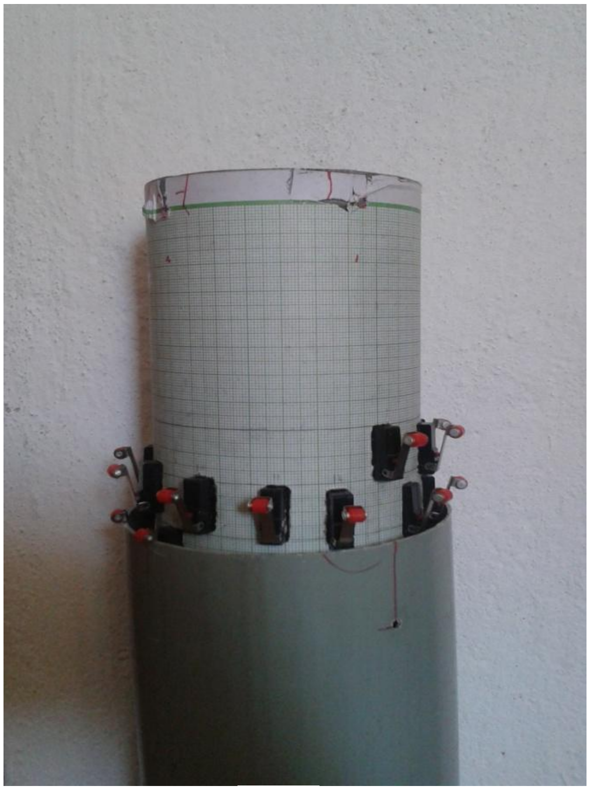
Variety of instruments are available for measuring road roughness but either those are costly or with regular and complicated calibration system. As well as further a complicated calculation may be involved to get the roughness.

The objective behind the development of a new device is to minimize the regular calibration of equipment and complicated calculation at a low cost with minimum error and easy handling.

3.2 PRINCIPLE OF OPERATION

The basic mechanism of the instrument is the relative motion of the movable hollow cylinder over a fixed cylinder fitted with switches at regular intervals. Here the switch pressed by the outer cylinder because of the movement over the inner cylinder due to the roughness of the surface gives the subsequent deviation of road surface from the mean position.

Here also the 'mid chord deviation' principle has been adopted as in the MERLIN. As the deviation of the outer cylinder from mean position due to roughness from the imaginary line joining the two touching points of the front and back wheel of the cycle on the road is measured. Here the observations can be taken minimum at a regular interval of 22 cm or higher as chosen earlier.



(a)

(b)

(c)

Fig 3.1 New Roughness Measuring Device with Various Components

3.3 GENERAL DESCRIPTION AND DESIGN PRINCIPLE

The figure above shows the new roughness measuring device.

- Here the internal cylinder having diameter 8.9cm is kept fixed with frame of the cycle and one hollow cylinder of diameter 10.8cm is allowed to move freely over the internal cylinder by just pressing the switches on it.
- The bottom outer cylinder is supported over a wheel set up which rolls over the road along with the motion of the cycle.
- The outer cylinder containing wheel will have the vertical motion according to the surface undulation and is restricted to lateral movements.
- At start up condition the bottom points of both wheels of cycle and the central wheels of the set up are supposed to be collinear.
- The internal cylinder consists of 21switches with a vertical interval of 2mm which is the least count of the instrument and the 11^{th} switch from bottom is the mean switch position.
- Switches are spaced up to 2cm to the top as well as bottom from mean position making a range of 4cm total.
- The switches are attached to a programmed microcontroller arrangement electronic circuit which sets the output of the switches as the input for data operation.
- A display is attached within the arrangement to validate the correctness of the switching system.
- Here the microcontroller is programmed to stores the data over a certain interval of road length for a predefined no of time. (manual input is given)
- A switch is attached at the rear wheel so that it will be pressed at every passing of spoke of rear wheel from which the distance travelled is easily calculated and the data of that switch is also fed to the microcontroller.

- A laptop will be connected during the survey to the output from the circuit through an usb.
- The readings taken are stored in systematic manner to get the output which will be saved in the laptop automatically in a text file.
- A 12v rechargeable battery is connected for supply of power to the circuit.

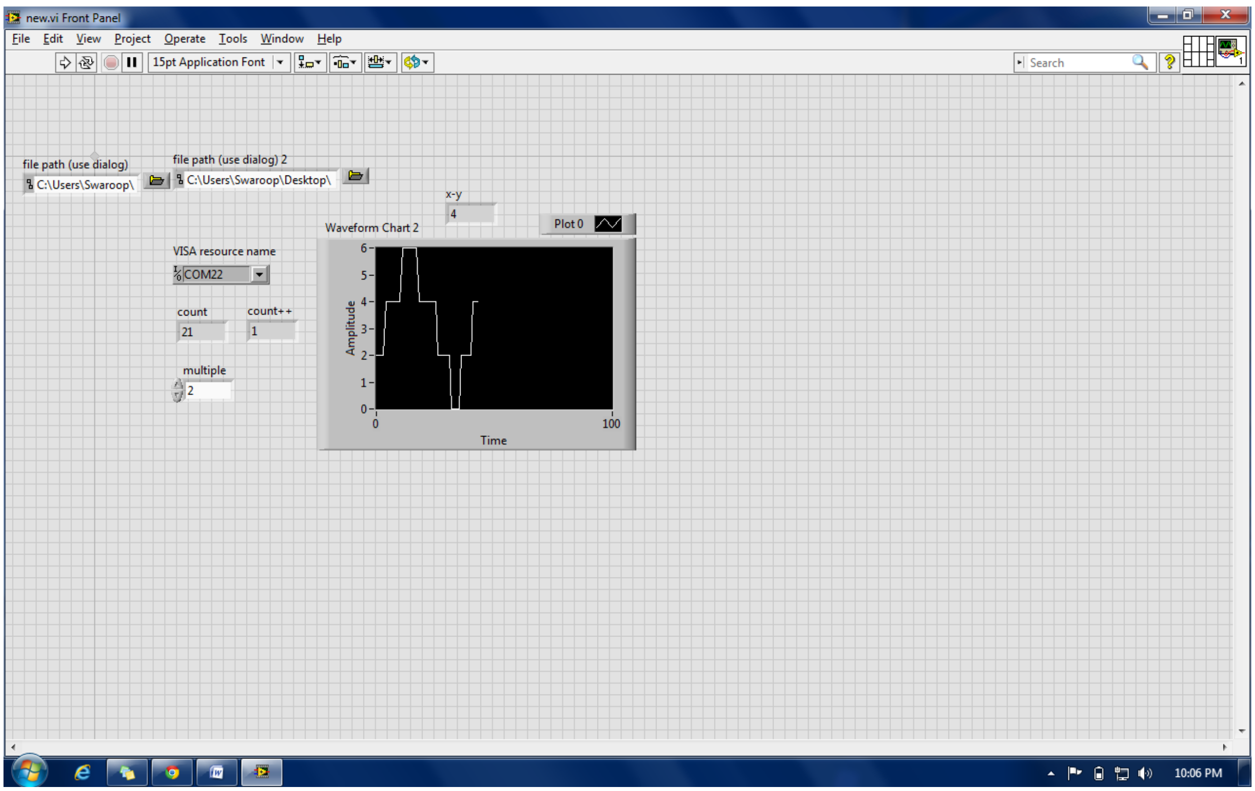


Fig 3.2 View of the software

3.4 METHOD OF USE

Before starting the survey all connections should be thoroughly checked e.g. the battery and the distance measuring switch input. Then the laptop should be connected by means of the USB cable and then run the software with providing the manual input of the no of readings required. Before start of the survey cycle should be made stand straight over a plane surface to check whether switches up to the mean position are pressed or not. These can be adjusted by changing the wheel position through the hole provided in the outer cylinder or small change can be done by changing the pressure of the tyres.

After the survey is started the straight position of cycle is to be maintained till the end of the survey while moving over the road. Here the switch will be pressed according the surface undulations with respect to the imaginary line joining the touching point of two tyres on the surface. The subsequent switch reading will be compared with the mean position and relative displacement will be recorded.

The collected will automatically be saved in the laptop after pressing the end in the software. The data in the text file can be analyzed and IRI can be calculated.

Fig 3.3 Road Roughness Measurement with New Device in Progress

3.5 CALCULATION OF IRI

Here IRI can be calculated from average slope as follows

Slope = Difference in readings [(difference in switch no*2) / 10)] at each interval / 220

(Where 2 is the multiplying factor as there are 21 no of switches having 20 gaps represents 40 mm deviation on the road so for each gap the deviation will be 40 / 20 = 2mm and 10 is divided to convert it to cm)

Average slope = sum of total slope / 200

IRI = average slope * 1000 (in m/km)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This report gives the details of roughness value done using all 3 instruments and its comparison study in IRI scale.

Roughness survey was done in 5 road stretches inside NIT campus using all three devices. After collecting roughness data using MERLIN, Auto level, and the new device, the results of the same are compared to validate the new device’s measuring capabilities and correctness.

List of name of the location of road stretches used for roughness survey

- Road in front of the college main gate
- Road in front of the campus main gate
- Mangala mandir Road
- Road in front of SAC
- Road behind V.S.Hall of Residence

4.2 CALCULATION OF IRI FROM SURVEY DATA COLLECTED USING MERLIN

One of the calculations using the data collected by MERLIN (Experiment no-3)

FOR UP ROAD STRETCH

From the chart

Total no of complete boxes = 15 (after eliminating up to box having 11^{th} cross from both top and bottom)

Total no of incomplete box = 0

D = 15 * 5 = 75mm (due to complete box)

IRI = 0.593 + (0.0471 * D) = 4.1255 m/km

FOR DOWN ROAD STRETCH

Total no of complete box = 15

Total no of incomplete box on either side = 1

D due to incomplete box = length of box / no of cross in that row = 5mm / 3 = 1.67mm

Total D = 15 * 5 + 1.67 = 76.67mm

IRI = 0.593 + (0.0471 * D) = 4.2 m/km

Average IRI of the road = 4.16 m/km

D and IRI values of other road are shown in the table no 4.1.

Table 4.1 MERLIN Results from Test Sections

TEST NO	ROAD SECTION	UP ROAD		DOWN ROAD		IRI of the road
		D in mm	IRI in m/km	D in mm	IRI in m/km	
1	College Main Gate	56.6	3.259	45.11	2.718	2.99
2	Campus Main Gate	122.5	6.363	61.25	3.478	4.92
3	Mangala Mandir	75	4.1255	76.67	4.2	4.16
4	SAC	42.67	2.6026	40	2.477	2.54
5	V.S. Hall	46.67	2.79	45	2.7125	2.75

Where $42 < D < 312$ and $2.4 < IRI < 15.9$

4.3 CALCULATION OF IRI FROM SURVEY DATA COLLECTED USING AUTO LEVEL

One of the data collected using Auto Level (Experiment No – 1, DOWN ROAD)

Table 4.2 Auto Level Data from Test Sections

Serial No.	Interval in m	Readings in cm	Difference	Slope = Difference / 220
1	2.2	135.5	0	0
2	4.4	133	2.5	0.0114
3	6.6	132.5	0.5	0.0027
4	8.8	132	0.5	0.0027
5	11	134	-2	0.0091
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
196	431.2	148	-1.5	0.00682
197	433.4	149.5	-1.5	0.00682
198	435.6	148.5	1	0.00454
199	437.8	148	0.5	0.0027
200	440	146.5	1.5	0.00682
Summation of slopes = 0.493				

Average slope = Sum of slopes / 200 = (as 200 readings were taken for a section)

IRI = Average slope * 1000 = m/km

Table 4.3 Auto Level Results

TEST NO	ROAD SECTION	UP ROAD		DOWN ROAD		IRI of the road
		Sum of Slopes	IRI in m/km	Sum of Slopes	IRI in m/km	
1	College Main Gate	0.61	3.05	0.493	2.46	2.755
2	Campus Main Gate	0.96	4.80	0.785	3.93	4.365
3	Mangala Mandir	0.752	3.76	0.82	4.10	3.93
4	SAC	0.51	2.55	0.475	2.375	2.46
5	V.S. Hall	0.482	2.41	0.544	2.72	2.565

4.4 CALCULATION OF IRI FROM SURVEY DATA COLLECTED USING NEW DEVICE

One of the data collected using New Device (Experiment No – 1, UP ROAD)

Table 4.4 Data of the New Device from Test Sections

Serial No.	Switch No	Difference(d)	Difference in cm D = [(d*2)/10]	Slope = D / 220
1	9	0	0	0
2	4	5	1	0.00454
3	2	2	0.4	0.00182
4	8	6	1.2	0.00545
5	11	3	0.6	0.00273
.	.	.		.
.	.	.		.
.	.	.		.
196	6	1	0.2	0.00091
197	13	7	1.4	0.00636
198	13	0	0	0
199	9	4	0.8	0.00364
200	10	1	0.2	0.00091
	Summation of slopes = 0.316			

Average slope = Sum of slopes / 200 = (as 200 readings were taken for a section)

IRI = Average slope * 1000= m/km

Table 4.5 Results Obtained Using New Device

TEST NO	ROAD SECTION	UP ROAD	DOWN ROAD	IRI of the road
		IRI in m/km	IRI in m/km	
1	College Main Gate	3.16	2.41	2.785
2	Campus Main Gate	4.63	4.125	4.3775
3	Mangala Mandir	4.15	3.44	3.82
4	SAC	2.42	2.20	2.31
5	V.S. Hall	2.154	2.53	2.342

4.5 COMPARISON OF IRI VALUES

4.5.1 MERLIN VS NEW DEVICE

Table 4.6 Comparison of Data of MERLIN vs. New Device

Test No.	Road Section	IRI (in m/km)		Difference in Readings	% Error	Average % Error
		MERLIN	New Device			
1	College Main Gate	2.99	2.785	0.205	6.86	9.988
2	Campus Main Gate	4.92	4.378	0.542	11.02	
3	Mangala Mandir	4.16	3.82	0.34	8.17	
4	SAC	2.54	2.31	0.23	9.05	
5	V.S. Hall	2.75	2.342	0.408	14.84	

4.5.2 AUTO LEVEL VS NEW DEVICE

Table 4.7 Comparison of Data of Auto Level vs. New Device

Test No.	Road Section	IRI (in m/km)		Difference in Readings	% Error	Average % Error
		Auto Level	New Device			
1	College Main Gate	2.755	2.785	0.03	1.09	3.795
2	Campus Main Gate	4.365	4.378	0.013	0.3	
3	Mangala Mandir	3.93	3.82	0.11	2.8	
4	SAC	2.46	2.31	0.15	6.098	
5	V.S. Hall	2.565	2.342	0.223	8.69	

4.5.3 MERLIN VS AUTO LEVEL

Table 4.8 Comparison of Data of MERLIN vs. Auto Level

Test No.	Road Section	IRI (in m/km)		Difference in Readings	% Error	Average % Error
		MERLIN	Auto Level			
1	College Main Gate	2.99	2.755	0.235	7.86	6.91
2	Campus Main Gate	4.92	4.365	0.555	11.28	
3	Mangala Mandir	4.16	3.93	0.23	5.53	
4	SAC	2.54	2.46	0.08	3.15	
5	V.S. Hall	2.75	2.565	0.185	6.73	

4.6 DISCUSSION

All the survey work was done on the roads inside NIT campus Rourkela. Using all three instruments data are recorded and then analyzed to get final results by different methods. Then the calculated IRI value of all roads using MERLIN and Auto Level are compared with the IRI values obtained using the new device for the analysis of error percentage. Here the percentages of error calculated are found to be small in case of some roads and moderate in case of others.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

A low cost roughness measuring device which is a simple attachment to a normal bi-cycle was designed for the measurement of road roughness. The same was validated with respect to the standard devices like MERLIN and Auto Level. Comparing all the instruments the advantage of this instrument over others are easy handling and less calibration involved, but in some cases the result obtained are differed up to some extent. Further modification is needed to achieve a great extent of accuracy. Also more survey needs to be carried out to compare the results more precisely and to find out the actual percentage of error in various road conditions. Finally it can be concluded that all three instruments have their own advantages over others in the road roughness survey.

5.2 FUTURE SCOPE

There are some recommendations for future work as listed below.

- Some more number of experiments needs to be carried out to compare and review the results to find the extent of accuracy can be achieved using the instruments on different road conditions.
- The instrument needs to be further modified to minimize the error and the working principle and design of the device is to be reviewed again.
- Some other roughness instruments should be used to compare and validate the results of new device.

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